

CLAIMS

What is claimed is:

- 1 1. An apparatus comprising:
 - 2 a first balancer to generate a first balancing signal from a first signal of a first index
 - 3 corresponding to a first frequency; and
 - 4 a first combiner coupled to the first balancer to combine the first balancing signal
 - 5 and a second signal of a second index corresponding to a second frequency, the second
 - 6 frequency being symmetrical to the first frequency with respect to a center frequency in a
 - 7 multi-carrier signal, the first combiner generating a first balanced signal corresponding to
 - 8 the second frequency.
- 1 2. The apparatus of claim 1 wherein the first balancer comprises:
 - 2 a first converter to convert the first signal into a first complex conjugate; and
 - 3 a first multiplier coupled to the first converter to multiply the first complex
 - 4 conjugate with a first balancing parameter, the first balancing parameter corresponding to
 - 5 the first frequency, the first multiplier generating the first balancing signal.
- 1 3. The apparatus of claim 1 wherein the first combiner includes a first
 - 2 subtractor to subtract the first balancing signal from the second signal to provide the first
 - 3 balanced signal.
- 1 4. The apparatus of claim 1 wherein the first balanced signal is a first desired
 - 2 signal scaled by a first complex factor.
- 1 5. The apparatus of claim 1 wherein the first signal is provided by a first sub-
 - 2 carrier demodulator operating at the first frequency.
- 1 6. The apparatus of claim 4 wherein the first desired signal is a first
 - 2 demodulated signal.
- 1 7. The apparatus of claim 1 further comprising:

2 a second balancer to generate a second balancing signal from the second signal; and
 3 a second combiner coupled to the second balancer to combine the second balancing
 4 signal with the first signal at a second frequency, the second combiner generating a second
 5 balanced signal at the first frequency.

1 8. The apparatus of claim 7 wherein the second balancer comprises:
 2 a second converter to convert the second signal into a second complex conjugate;
 3 and
 4 a second multiplier coupled to the second converter to multiply the second complex
 5 conjugate with a second balancing parameter, the second balancing parameter
 6 corresponding to the second frequency, the second multiplier generating the second
 7 balancing signal.

1 9. The apparatus of claim 7 wherein the second combiner includes a second
 2 subtractor to subtract the second balancing signal from the first signal to provide the
 3 second balanced signal.

1 10. The apparatus of claim 7 wherein the second balanced signal is a second
 2 desired signal scaled by a second complex factor.

1 11. The apparatus of claim 7 wherein the second signal is provided by a second
 2 sub-carrier demodulator operating at the second frequency.

1 12. The apparatus of claim 10 wherein the second desired signal is a second
 2 demodulated signal.

1 13. The apparatus of claim 2 wherein the first balancing parameter is a ratio
 2 between output of the second sub-carrier demodulator and a conjugate output of the first
 3 sub-carrier demodulator when the multi-carrier signal contains a first sub-carrier signal
 4 modulated by a non-null complex number and a second sub-carrier signal modulated by a
 5 null complex number during a training process.

1 14. The apparatus of claim 8 wherein the second balancing parameter is a ratio
2 between output of the first sub-carrier demodulator and a conjugate output of the second
3 sub-carrier demodulator when the multi-carrier signal contains a first sub-carrier signal
4 modulated by a null complex number and a second sub-carrier signal modulated by a non-
5 null complex number during a training process .

1 15. The apparatus of claim 1 wherein the first signal is a first original signal to
2 be transmitted.

1 16. The apparatus of claim 1 wherein the first desired signal is provided to a
2 first sub-carrier modulator operating at the first frequency.

1 17. The apparatus of claim 16 further comprising:
2 a second balancer to generate a second balancing signal from the second signal; and
3 a second subtractor coupled to the second balancer to subtract the second balancing
4 signal from the first signal at a second frequency, the second subtractor generating a
5 second balanced signal at the first frequency.

1 18. The apparatus of claim 17 wherein the second balancer comprises:
2 a second converter to convert the second signal into a second complex conjugate;
3 and
4 a second multiplier coupled to the second converter to multiply the second complex
5 conjugate with a second balancing parameter, the second balancing parameter
6 corresponding to the second frequency, the second multiplier generating the second
7 balancing signal.

1 19. The apparatus of claim 17 wherein the second balanced signal is a second
2 desired signal scaled by a second complex factor.

1 20. The apparatus of claim 19 wherein the second desired signal is provided to
2 a second sub-carrier modulator operating at the second frequency.

1 21. The apparatus of claim 20 wherein one of the first and second balancing
2 parameters is obtained during a training process.

1 22. The apparatus of claim 21 wherein the first balancing parameter is derived
2 from outputs of first and second sub-carrier demodulators operating at first and second
3 frequencies when the multi-carrier signal is generated from the first and second sub-carrier
4 modulators receiving the first and second desired signal, the first desired signal being a
5 non-null complex number and the second desired signal being a null complex number
6 during the training process.

1 23. The apparatus of claim 21 wherein the second balancing parameter is
2 derived from outputs of first and second sub-carrier demodulators operating at first and
3 second frequencies when the multi-carrier signal is generated from the first and second
4 sub-carrier modulators receiving the first and second desired signal, the first desired signal
5 being a null complex number and the second desired signal being a non-null complex
6 number during the training process.

1 24. A method comprising:
2 generating a first balancing signal from a first signal of a first index corresponding
3 to a first frequency using a first balancer; and
4 combining the first balancing signal and a second signal of a second index
5 corresponding to a second frequency using a first combiner, the second frequency being
6 symmetrical to the first frequency with respect to a center frequency in a multi-carrier
7 signal, the first combiner generating a first balanced signal corresponding to the second
8 frequency.

1 25. The method of claim 24 wherein generating a first balancing signal
2 comprises:
3 converting the first signal into a first complex conjugate by a first converter; and

4 multiplying the first complex conjugate with a first balancing parameter by a first
5 multiplier, the first balancing parameter corresponding to the first frequency, the first
6 multiplier generating the first balancing signal.

1 26. The method of claim 24 wherein the first combiner includes a first
2 subtractor to subtract the first balancing signal from the second signal to provide the first
3 balanced signal.

1 27. The method of claim 24 wherein the first balanced signal is a first desired
2 signal scaled by a first complex factor.

1 28. The method of claim 27 wherein the first signal is provided by a first sub-
2 carrier demodulator operating at the first frequency.

1 29. The method of claim 28 wherein the first desired signal is a first
2 demodulated signal.

1 30. The method of claim 29 further comprising:
2 generating a second balancing signal from the second signal using a second
3 balancer; and
4 combining the second balancing signal with the first signal at a second frequency
5 using a second combiner, the second combiner generating a second balanced signal at the
6 first frequency.

1 31. The method of claim 30 wherein generating the second balancing signal
2 comprises:
3 converting the second signal into a second complex conjugate by a second
4 converter; and
5 multiplying the second complex conjugate with a second balancing parameter by a
6 second multiplier, the second balancing parameter corresponding to the second frequency,
7 the second multiplier generating the second balancing signal.

1 32. The method of claim 30 wherein the second combiner includes a second
2 subtractor to subtract the second balancing signal from the first signal to provide the
3 second balanced signal.

1 33. The method of claim 30 wherein the second balanced signal is a second
2 desired signal scaled by a second complex factor.

1 34. The method of claim 33 wherein the second signal is provided by a second
2 sub-carrier demodulator operating at the second frequency.

1 35. The method of claim 34 wherein the second desired signal is a second
2 demodulated signal.

1 36. The method of claim 30 wherein the first balancing parameter is derived
2 from outputs of the first and second sub-carrier demodulators when the multi-carrier signal
3 contains the first sub-carrier signal modulated by a non-null complex number and the
4 second sub-carrier signal modulated by a null complex number during a training process.

1 37. The method of claim 30 wherein the second balancing parameter is derived
2 from outputs of the first and second sub-carrier demodulators when the multi-carrier signal
3 contains the first sub-carrier signal modulated by a null complex number and the second
4 sub-carrier signal modulated by a non-null complex number during a training process.

1 38. The method of claim 26 wherein the first signal is a first original signal to
2 be transmitted.

1 39. The method of claim 38 wherein the first desired signal is provided to a first
2 sub-carrier modulator operating at the first frequency.

1 40. The method of claim 39 further comprising:

2 generating a second balancing signal from the second signal by a second balancer;
 3 and
 4 subtracting the second balancing signal from the first signal at a second frequency
 5 by a second subtractor, the second subtractor generating a second balanced signal at the
 6 first frequency.

1 41. The method of claim 40 wherein generating the second balancing signal
 2 comprises:
 3 converting the second signal into a second complex conjugate by a second
 4 converter; and
 5 multiplying the second complex conjugate with a second balancing parameter by a
 6 second multiplier, the second balancing parameter corresponding to the second frequency,
 7 the second multiplier generating the second balancing signal.

1 42. The method of claim 40 wherein the second balanced signal is a second
 2 desired signal scaled by a second complex factor.

1 43. The method of claim 42 wherein the second desired signal is provided to a
 2 second sub-carrier modulator operating at the second frequency.

1 44. The method of claim 43 wherein one of the first and second balancing
 2 parameters is obtained during a training process.

1 45. The method of claim 44 wherein the first balancing parameter is derived
 2 from outputs of first and second sub-carrier demodulators operating at first and second
 3 frequencies when the multi-carrier signal is generated from the first and second sub-carrier
 4 modulators receiving the first and second desired modulating signal, the first desired signal
 5 being a non-null complex number and the second desired signal being a null complex
 6 number during the training process.

1 46. The method of claim 44 wherein the second balancing parameter is derived
 2 from outputs of first and second sub-carrier demodulators operating at first and second

3 frequencies when the multi-carrier signal is generated from the first and second sub-carrier
4 modulators receiving the first and second desired modulating signal, the first desired signal
5 being a null complex number and the second desired signal being a non-null complex
6 number during the training process.

1 47. A system comprising:
2 in-phase (I) and quadrature (Q) processing chains to generate I and Q samples from
3 a multi-carrier signal having P sub-carrier signals at P carrier frequencies;
4 a bank of demodulators coupled to the I and Q processing chains to demodulate the
5 P sub-carrier signals, the bank of demodulators generating P demodulated signals; and
6 a balancing unit coupled to the bank of demodulators to restore P original signals
7 from the P demodulated signals, the balancing unit including P basic blocks, each of the
8 basic blocks comprising:
9 a first balancer to generate a first balancing signal from a first signal at a
10 first frequency, and
11 a first subtractor coupled to the first balancer to subtract the first balancing
12 signal from a second signal at a second frequency, the second frequency being symmetrical
13 to the first frequency with respect to a center frequency in the multi-carrier signal, the first
14 subtractor generating a first balanced signal at the second frequency.

1 48. The system of claim 47 wherein the first balancer comprises:
2 a first converter to convert the first signal into a first complex conjugate; and
3 a first multiplier coupled to the first converter to multiply the first complex
4 conjugate with a first balancing parameter, the first balancing parameter corresponding to
5 the first frequency, the first multiplier generating the first balancing signal.

1 49. The system of claim 47 wherein the first combiner includes a first
2 subtractor to subtract the first balancing signal from the second signal to provide the first
3 balanced signal.

1 50. The system of claim 47 wherein the first balanced signal is a first desired
2 signal scaled by a first complex factor.

1 51. The system of claim 50 wherein the first signal is provided by a first sub-
2 carrier demodulator operating at the first frequency.

1 52. The system of claim 51 wherein the first desired signal is a first
2 demodulated signal.

1 53. The system of claim 52 wherein each of the basic blocks further
2 comprising:
3 a second balancer to generate a second balancing signal from the second signal; and
4 a second combiner coupled to the second balancer to combine the second balancing
5 signal with the first signal at a second frequency, the second combiner generating a second
6 balanced signal at the first frequency.

1 54. The system of claim 53 wherein the second balancer comprises:
2 a second converter to convert the second signal into a second complex conjugate;
3 and
4 a second multiplier coupled to the second converter to multiply the second complex
5 conjugate with a second balancing parameter, the second balancing parameter
6 corresponding to the second frequency, the second multiplier generating the second
7 balancing signal.

1 55. The system of claim 53 wherein the second combiner includes a second
2 subtractor to subtract the second balancing signal from the first signal to provide the
3 second balanced signal.

1 56. The system of claim 53 wherein the second balanced signal is a second
2 desired signal scaled by a second complex factor.

1 57. The system of claim 56 wherein the second signal is provided by a second
2 sub-carrier demodulator operating at the second frequency.

1 58. The system of claim 57 wherein the second desired signal is a second
2 demodulated signal.

1 59. The system of claim 53 wherein the first balancing parameter is derived
2 from outputs of the first and second sub-carrier demodulators when the multi-carrier signal
3 contains the first sub-carrier signal modulated by a non-null complex number and the
4 second sub-carrier signal modulated by a null complex number during a training process.

1 60. The system of claim 53 wherein the second balancing parameter is derived
2 from outputs of the first and second sub-carrier demodulators when the training multi-
3 carrier signal contains the first sub-carrier signal modulated by a null complex number and
4 the second sub-carrier signal modulated by a non-null complex number during a training
5 process.

1 61. The system of claim 49 wherein the first signal is a first original signal to be
2 transmitted.

1 62. The system of claim 61 wherein the first desired signal is provided to a first
2 sub-carrier modulator operating at the first frequency.

1 63. The system of claim 62 further comprising:
2 a second balancer to generate a second balancing signal from the second signal; and
3 a second subtractor coupled to the second balancer to subtract the second balancing
4 signal from the first signal at a second frequency, the second subtractor generating a
5 second balanced signal at the first frequency.

1 64. The system of claim 63 wherein the second balancer comprises:
2 a second converter to convert the second signal into a second complex conjugate;
3 and
4 a second multiplier coupled to the second converter to multiply the second complex
5 conjugate with a second balancing parameter, the second balancing parameter

6 corresponding to the second frequency, the second multiplier generating the second
7 balancing signal.

1 65 The system of claim 63 wherein the second balanced signal is a second
2 desired signal scaled by a second complex factor.

1 66. The system of claim 65 wherein the second desired signal is provided to a
2 second sub-carrier modulator operating at the second frequency.

1 67. The system of claim 66 wherein one of the first and second balancing
2 parameters is obtained during a training process.

1 68. The system of claim 67 wherein the first balancing parameter is derived
2 from outputs of first and second sub-carrier demodulators operating at first and second
3 frequencies when the multi-carrier signal is generated from the first and second sub-carrier
4 modulators receiving the first and second desired modulating signal, the first desired signal
5 being a non-null complex number and the second desired signal being a null complex
6 number during the training process.

1 69. The system of claim 67 wherein the second balancing parameter is derived
2 from outputs of first and second sub-carrier demodulators operating at first and second
3 frequencies when the training multi-carrier signal is generated from the first and second
4 sub-carrier modulators receiving the first and second desired modulating signal, the first
5 desired signal being a null complex number and the second desired signal being a non-null
6 complex number during the training process.

1 70. The apparatus of claim 1 wherein at least one of the first and second indices
2 corresponds to a zero index.

1 71. The apparatus of claim 70 wherein at least one of the first and second
2 signals corresponds to one of the center frequency and a DC of a baseband signal of the
3 multi-receiver signal.